UTILIZTION OF WASTE

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UTILIZATION OF COAL-MINING WASTE IN THE PRODUCTION OF BUILDING CERAMIC MATERIALS

V. G. Lemeshev,[1] I. K. Gubin,[1] Yu. A. Savel'ev,[1] D. V. Tumanov,[1] and D. O. Lemeshev[1]

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It is established that coal-mining waste used in joint (moist or dry) preparation of mixtures is a promising material for the production of building ceramics. The waste content in the batch may reach 50%. The quality of the products made using coal-mining waste from the Moscow Region fully meets the requirements of GOST 6841–84 for respective products.

Many producers of construction products based on argillaceous minerals experience substantial difficulties in getting high-quality raw materials [1, 2].

One of the ways for solving this problem is the utilization of technogenic products for the purpose of partial or complete replacement of argillaceous minerals in the technology of building materials. Such technogenic waste that currently takes up enormous areas of fertile lands includes ash generated by thermal power plants burning coal, coal-mining waste, some kinds of metallurgical slag, oil shale processing waste, and household waste.

The trend observed in the world power industry in the last 20 – 25 years implies the conversion of various industries, including thermal power plants from liquid and gaseous fuel to coal, which results in sharply increased quantities of ash and slag generated. The amount of this kind of waste by the end of 1980s was equal to around 500 million tons per year, which corresponded to the volume of argillaceous minerals annually mined in the world. One should also take into account the coal-mining waste, whose quantity is approximately equal to that of the ash or even larger, as well as the waste generated in processing oil shale, whose annual volume is nearly equal to the annual volume of clay extraction in Russia. The technogenic products for decades keep been accumulated on the sites of mining enterprises, occupy enormous area of fertile land, and under the effect of atmospheric factors intensely pollute the ambient environment.

There are currently over 1000 known technogenic products that are promising for recycling. Out of that number, 780 products are included in various databases as an object of potential application, however only 60 of them are actually recycled [3].

The estimate of the effect of various types of waste on the environment is a time-consuming and complicated process. Considering that the development of the maximum permissible concentration (MPC) for just one material takes 2 – 3 years [4], it is easy to imagine the difficulties involved in researching this problem. Furthermore, MPCs are developed based on the calculations of average statistical sanitary norms and have to be agreed with numerous agencies, who frequently attempt to unjustifiably raise the MPC values [5].

An incorrect approach to understanding the problem of accumulation and recycling various waste resources resulted in the fact that the environment-protection industry of the former USSR countries is totally underdeveloped and, accordingly, incapable of solving the problems it confronts. For instance, there is only one waste-recycling factory with 120-person staff currently functioning in Russia, whereas this industry in the USA employs over one million people.

Calculations indicate that comprehensive utilization of raw materials and technogenic products makes it possible to increase the production of many types of products by 25 – 30%. Considering the saving of expenses needed for geological survey, development, and storage of raw materials, land recultivation and environmental protection activities, the production cost decreases 2 – 4 times compared to the use of materials extracted according to the traditional scheme [6]. The economical effect obtained in the utilization of technogenic products to a large extent id caused by the fact that they can be recycled without investing into the extraction of raw materials. In the case when technogenic pro-

[1] Moscow Institute of Municipal Economics and Construction, Moscow, Russia; D. I. Mendeleev Russian Chemical Engineering University, Moscow, Russia.

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TABLE 1

Mixture	Mass content, %*	
	clay	coal-mining waste
1	80	20
2	70	30
3	60	40
4	50	50

* Water content in al mixtures was 8% (above 100%).

ducts are recycled on the site of their generation, i.e., in large industrial districts with a high demand for construction materials, the transportation expenses are minimal.

The main types of technogenic products in Russia are power plant ash, coal mining waste, waste generated at mining-and-concentration works and metallurgical plants, oil shale processing waste, and household waste.

Metallurgical waste is the form of granulated slag is nearly totally recycled in the production of binding agents [7].

The experience of industrial recycling of waste from the Kachkanarskii Mining-and-Concentration Works in the production of ceramic tiles at the Kuchinskii Ceramic Works has shown that these technogenic products (especially those containing minerals of the pyroxene class) can be without great expenses utilized in the production of ceramic construction materials [8]. The overall volume of the concentration waste accumulated in Russia reaches 50 million tons per year, whereas the amount of recycled materials amounts to a few tens of thousand tons.

The most promising for use as auxiliary or main materials in the production of construction materials, including ceramics, is the coal-mining waste and thermal power plant ash, in view of their mineralogical composition and volume accumulated. The technogenic materials of this group are large-scale mineral wastes; the quantity of coal-concentration waste reaches 90 million tons per year and the ash-and-slag waste from power plants — around 100 million tons per year [9].

Unfortunately, Russia at the moment does not have an integrated program of using fuel-bearing mineral waste in the building industry, similar to the “Raw Materials” program that used to exist in the USSR. Only 1% of the annually generated waste of this group is currently recycled in this way. At the same time, the recent experience of industrial recycling of technogenic products in the production of construction materials indicates that these waste products can be used not only as correcting and auxiliary additives, but as main materials for construction ceramics as well.

The similarity of the chemical-mineralogical composition of coal-mining waste to that of natural argillaceous minerals makes it possible to regard it as an inexhaustible source of argillaceous material of a satisfactory quality. Thus, the chemical composition of the coal-mining waste from the Moscow coal basin and the Tula deposit is as following (wt.%): 38.93 SiO_2, 16.08 Al_2O_3, 4.20 Fe_2O_3, 1.54 CaO, 0.96 MgO, 0.62 R_2O, and 36.89 calcination loss (TiO_2 and FeO are not identified in the composition).

The physicochemical basis of a ceramic production based on argillaceous materials (including the entrainment ash and coal-mining waste) is the synthesis of primary mullite in firing, which determines the main physicomechanical properties of the final product.

The Moscow Municipal Economics Institute since 1980s has been systematically researching the utilization of the entrainment ash from the Luberetskii thermal power plant and coal-mining waste in mixtures for ceramic construction materials. The main materials in these mixtures were clays from virtually all known deposits in Russia: Mikhnevskoe, Vladimirskoe, Shchelkovskoe, Egor’evskoe, Kurganskoe, etc. The composition of the experimental mixtures is given in Table 1.

The molding powder was prepared by two methods: moist and dry.

According to the first method, clay was primarily liquefied in a laboratory mixer to 50 % moisture. Coal-mining waste was milled in a laboratory ball mill by the moist method with the material : balls : water ratio equal to 1 : 2 : 0.4 for 1, 3, and 5 h. The slips prepared in this way were mixed for 15 min and then dried to a moisture of 8%.

The molding powder of moisture 8% was used to mold samples of diameter 40 and height 50 mm on a laboratory hydraulic press at the unit pressure of 20 and 40 MPa; next, the samples were dried to 2% moisture and fired at 950°C with a 2-h exposure at this temperature.

According to the second method, the molding powder was prepared by joint milling of clay and coal-mining waste in a laboratory ball mill with the material : balls ratio equal to 1 : 3 for 1, 3, and 5 h, after which the mixture was brought to moisture 8%.

TABLE 2

Material	Mass content, %									
	SiO_2	Al_2O_3	TiO	Fe_2O_3	CaO	MgO	SO_3	K_2O	Na_2O	calcination loss
Clay:										
Latnenskoe (TU 14-18-8-152)	54.43	29.06	29.06	1.50	1.19	0.66	0.5	1.96	1.96	9.96
Kudinovskoe (TU 400-1508-1)	68.60	20.20	20.20	1.44	0.83	0.60	–	2.87	2.87	5.40

TABLE 3

Mixture*	Milling duration, h	Molding pressure, MPa	Shrinkage, %	Water absorption, %	Average density, g/cm^3	Porosity, %	Compressive strength, MPa
Latnenskoe clay							
1	1	40	0.17	20.5	3.24	66.4	62.7
2			0.27	16.5	3.15	52.0	52.4
3			0.39	12.0	3.12	37.4	34.6
4			0.50	10.5	3.03	32.4	29.5
1	3	40	0.27	11.0	3.17	35.0	40.1
2			0.36	9.00	2.96	26.5	31.9
3			0.44	6.00	2.83	17.0	25.0
4			0.62	5.20	2.75	14.3	19.5
Kudinovskoe clay							
1	3	30	1.17	17.4	1.54	26.7	44.2
2			0.91	21.1	1.64	32.3	27.1
3			0.72	28.0	1.42	41.2	18.6
4			0.64	38.2	1.39	54.3	12.0
1	3	40	1.25	16.6	1.57	25.9	46.8
2			1.00	19.5	1.50	29.2	32.1
3			0.85	25.1	1.44	36.1	20.1
4			0.75	37.3	1.40	52.0	12.7

* Moisture of samples from Latnenskoe and Kudinovskoe clay was 7.5 and 7.4%, respectively.

TABLE 4

Mixture based on Latnenskoe clay*	Milling duration, h	Molding pressure MPa	Shrinkage, %	Water absorption, %	Average density, g/cm^3	Porosity, %	Compressive strength, MPa
1	5	20	2.00	12.3	1.84	22.6	89.7
2			2.00	15.0	1.78	26.7	84.0
3			1.80	16.0	1.76	28.1	59.8
4			1.30	21.3	1.49	31.7	29.7
1	5	40	1.90	10.9	1.88	20.5	98.3
2			1.60	12.0	1.80	20.8	95.2
3			1.00	12.5	1.73	21.7	84.3
4			0.50	20.2	1.47	29.7	42.7

* Moisture in all cases was 7.4%.

The molding powder prepared in this way was used to mold samples of diameter 40 and height 50 mm on a laboratory hydraulic press at the unit pressure of 20, 30, and 40 MPa; next, the samples were dried to 2% moisture and fired at 950°C with a 2-h exposure at this temperature.

The optimum testing results (taking as example, the clays from the Latnenskoe and Kudinovskoe deposits, see Table 2) registered using the moist and dry methods are indicated in Tables 3 and 4, respectively.

The analysis of the physicomechanical properties of samples indicates that coal-mining waste can serve as an inexhaustible source of high-quality material for the production of ceramic building materials. The joint milling of the materials (clay and coal-mining waste) by the moist method provides for a substantial improvement of all physicomechanical properties of the products. At the same time, using the dry method makes it possible to obtain high-quality products without substantial capital costs.

Increasing the mass content of the coal-mining waste in a batch from 25 to 50% leads to a gradual decrease in the mechanical strength of the samples and increases their porosity. However, the compression strength of samples containing up to 50% waste remains sufficiently high.

Extending the batch milling duration makes it possible to produce articles of a higher mechanical strength even with the maximum waste content.

The analysis of the obtains results suggests that the reaction capacity of the coal-mining waste subjected to an effective mechanical impact grows to such a degree, that it starts intensely reacting with the argillaceous minerals. At the same time, the coal-mining waste in drying behaves as normal clay and in firing undergoes the same stages as argillaceous minerals: decomposition of carbonates, formation of mullite, etc. [10].

It should be noted as well that the prototype batch of tiles for interior wall facing produced on the conveyor production line of the Kuchinskii Ceramic Works from molding powder containing 70% Kudinovskoe clay and 30% coal-mining waste with a moisture of 6% fully meets the requirements of GOST 6841–84.

Thus, the coal-mining waste after a corresponding treatment is a promising material for the ceramic industry.

The joint preparation of mixtures using the moist method provides for obtaining products with good physicomechanical parameters, even with an increased waste content in the mixture. The joint preparation of mixtures using the dry method provides for getting products with sufficiently high physicomechanical parameters even with 50% content of coal-mining waste in the mixture.

The recycling of waste in mixtures for construction ceramics makes it possible to improve the color of finished products (up to a light creamy shade), even when red-burning clay is used as the main material of the mixture.

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